



### **Some Improvements in H-PDLCs**

**Nonuniformities and required drive potentials have been reduced.**

*Goddard Space Flight Center, Greenbelt, Maryland*

Some improvements have been made in the formulation of holographically formed polymer-dispersed liquid crystals (H-PDLCs) and in the fabrication of devices made from these materials, with resulting improvements in performance. H-PDLCs are essentially volume Bragg gratings. Devices made from H-PDLCs function as electrically switchable reflective filters. Heretofore, it has been necessary to apply undesirably high drive voltages in order to switch H-PDLC devices.

Many scientific papers on H-PDLCs and on the potential utility of H-PDLC devices for display and telecommunication applications have been published. However, until now, little has been published about improving quality control in synthesis of H-PDLCs and fabrication of H-PDLC devices to minimize (1) spatial nonuniformities within individual devices, (2) nonuniformities among nominally identical devices, and (3) variations in performance among nominally identical devices. The improvements reported here are results of a research effort directed partly toward solving these quality-control problems and partly toward reducing switching voltages.

The quality-control improvements include incorporation of a number of process controls to create a relatively robust process, such that the H-PDLC devices fabricated in this process are more nearly uniform than were those fabricated in a prior laboratory-type process. The improved process includes ultrasonic mixing, ultrasonic cleaning, the use of a micro dispensing technique, and the use of a bubble press.

The ultrasonic mixing (in contradistinction to other types of mixing) creates more nearly uniform H-PDLCs. The ultrasonic cleaning removes chips of indium tin oxide (which is electrically conductive), whereas, heretofore, chips of indium oxide remaining at the edges of H-PDLC devices have caused electrical short circuits. The micro-dispensing technique enables the emplacement of precisely the amount of H-PDLC required for a given cell volume so that the H-PDLC can be pressed between glass substrates to a precise inter-substrate distance defined by spacers. The bubble press enables the application of the correct pressure needed to push the substrates against the H-PDLC and the controlled

amounts of spacers, thereby also helping to minimize nonuniformity of gaps among cells.

The drive-voltage problem has been partially solved by development of a formulation that includes an additive that reduces the magnitude of the required drive voltage. Devices that can be switched from a reflectivity of  $\approx 0.5$  to a reflectivity near zero by applying relatively low drive potentials ( $<100$  V) have been demonstrated. It has been postulated that the reduction in the magnitude of the required drive voltage is attributable to a reduction in the surface anchoring energy.

In cases of fabrication of multilayer devices comprising stacked H-PDLC panels, the improved process also includes the use of thin glass substrates with appropriate optical coatings. Devices comprising, variously, five or ten stacked panels have been fabricated thus far.

*This work was done by Gregory P. Crawford and Liuliu Li of Brown University for Goddard Space Flight Center. Further information is contained in a TSP (see page 1). GSC-14920-1*

### **Multiple-Bit Differential Detection of OQPSK**

**This could be the best-known differential-detection method for OQPSK.**

*NASA's Jet Propulsion Laboratory, Pasadena, California*

A multiple-bit differential-detection method has been proposed for the reception of radio signals modulated with offset quadrature phase-shift keying (offset QPSK or OQPSK). The method is also applicable to other spectrally efficient offset quadrature modulations.

This method is based partly on the same principles as those of a multiple-symbol differential-detection method for *M*-ary QPSK, which includes QPSK (that is, non-offset QPSK) as a special case. That method was introduced more

than a decade ago by the author of the present method as a means of improving performance relative to a traditional (two-symbol observation) differential-detection scheme. Instead of symbol-by-symbol detection, both that method and the present one are based on a concept of maximum-likelihood sequence estimation (MLSE). As applied to the modulations in question, MLSE involves consideration of (1) all possible binary data sequences that could have been received during an observation time of some number,  $N$ , of symbol periods and

(2) selection of the sequence that yields the best match to the noise-corrupted signal received during that time. The performance of the prior method was shown to range from that of traditional differential detection for short observation times (small  $N$ ) to that of ideal coherent detection (with differential encoding) for long observation times (large  $N$ ).

The mathematical derivation of the present method began with the identification of an equivalent precoded continuous phase modulation (CPM)

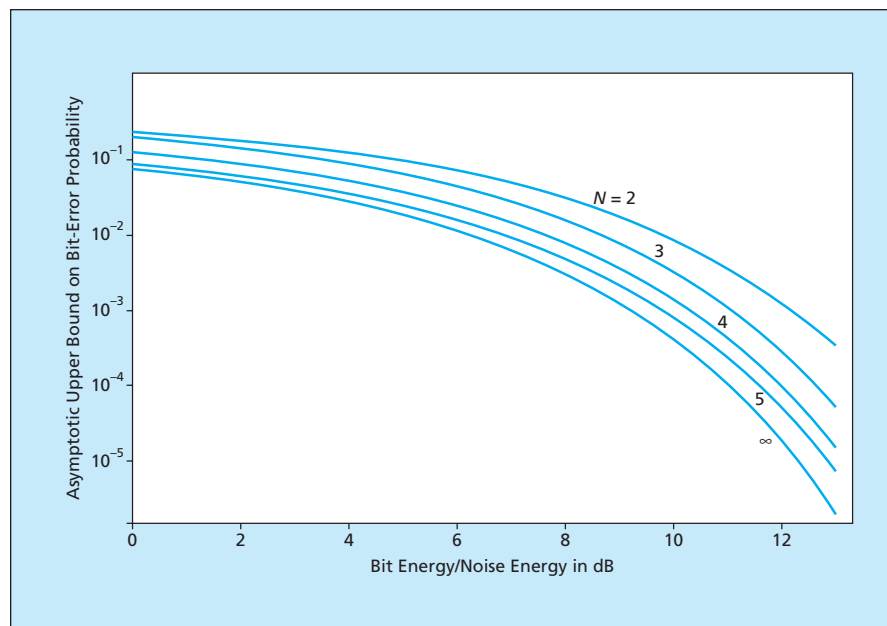
structure, first for OQPSK and then differentially encoded OQPSK. It was shown that the precoding needed to

obtain the equivalence is such as to result in a ternary (0,-1,+1) CPM input alphabet that, during any given one-bit

observation period, is equivalent to a binary alphabet. Next, some results of prior work by the same author on maximum-likelihood block detection of noncoherent CPM were utilized to derive a maximum-likelihood decision metric and an associated receiver structure for the precoded version that equivalently represents differentially encoded OQPSK.

The figure presents some results of computations of the bit-error performance of the present method. Because of its maximum-likelihood basis, this method is expected to be the most power-efficient method of differential detection of OQPSK. Furthermore, on the basis of the resemblance of this method to the prior multiple-symbol method of differential detection of non-offset QPSK, the performance of a receiver based on this method is expected to improve with increasing  $N$ .

*This work was done by Marvin Simon of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1).  
NPO-30777*



The **Asymptotic Upper Bound on the Average Bit-Error Probability** for a receiver based on the proposed method has been computed as a function of the bit-energy/noise-energy ratio and the number ( $N$ ) of bit periods in the observation time.

## Absolute Position Encoders With Vertical Image Binning

Conversion rates can exceed 20 kHz.

*Goddard Space Flight Center, Greenbelt, Maryland*

Improved optoelectronic pattern-recognition encoders that measure rotary and linear 1-dimensional positions at conversion rates (numbers of readings per unit time) exceeding 20 kHz have been invented. Heretofore, optoelectronic pattern-recognition absolute-position encoders have been limited to conversion rates <15 Hz — too low for emerging industrial applications in which conversion rates ranging from 1 kHz to as much as 100 kHz are required. The high conversion rates of the improved encoders are made possible, in part, by use of vertically compressible or binnable (as described below) scale patterns in combination with modified readout sequences of the image sensors [charge-coupled devices (CCDs)] used to read the scale patterns. The modified readout sequences and the processing of the images thus read out are amenable to implementation by use of modern, high-speed, ultra-compact microprocessors and digital signal processors or field-programmable gate arrays. This combination of improvements makes it

possible to greatly increase conversion rates through substantial reductions in all three components of conversion time: exposure time, image-readout time, and image-processing time.

In a typical prior optoelectronic pattern-recognition absolute-position encoder, the CCD is oriented with its horizontal axis parallel to the axis along

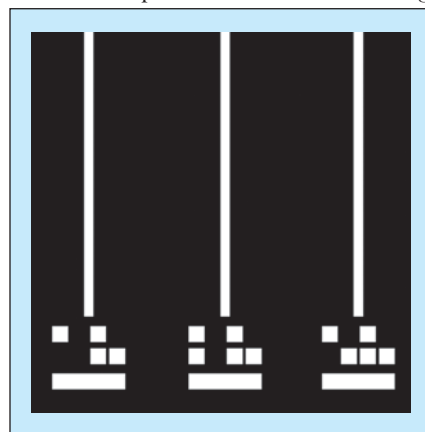


Figure 1. Previous Patterns Contain Both Vertical and Horizontal Information and must be read out pixel-by-pixel.

which the position of the scale pattern is to be measured. The pattern includes vertically oriented fiducial bars plus small rectangles or squares, representing code bits, that serve to uniquely identify the fiducial bars (see Figure 1). The lower limit on conversion time is determined primarily by the exposure time and the time required to read out the

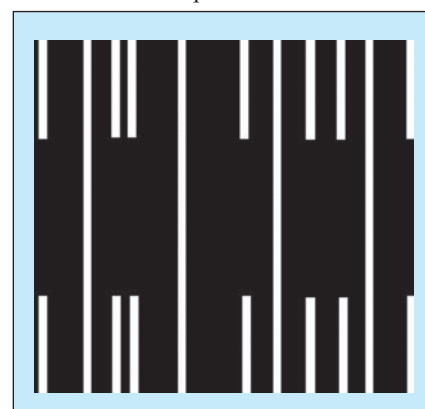


Figure 2. Portion of New Scale Pattern, partly resembling common bar code, is representative of vertically binnable patterns used in encoders of the type described in the text.